DECOMPOSITION OF WILD RICE *(Zizania aquatica L.)* STRAW AND ITS EFFECT ON THE DEPLETION OF OXYGEN DURING WINTER IN NATURAL LAKES OF NORTHWESTERN ONTARIO

Pritam Sain

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ABSTRACT

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The decomposition of wild rice *(Zizania aquatica* L.) straw was studied by placing 25 × 15 cm size nylon bags containing 20 g of air dried straw in Lulu Lake, a typical shallow lake, and in West Bay, a waterbody representing a river system.

The rate of decomposition during winter months was 0.16% of the total weight of straw per day, with an oxygen consumption rate of 0.718 g/m^2/day. Using this datum, along with other available data on the rate of oxygen consumption in sediments and water columns of lakes, a model was developed which related mean water depth to the percent surface area of a lake where the production of wild rice does not limit the activity of most fish.

The model showed that winter kill of fish would occur, even without any wild rice growth, in oligotrophic and eutrophic lakes with mean water depths of 1.5 and 4.3 metres or less, respectively. In oligotrophic lakes with mean water depths between 1.5 and 14.9 metres, and in eutrophic lakes with mean water depths between 4.3 and 17.7 metres, a certain percentage of the total surface area of the lakes can be used for growing wild rice, without limiting the oxygen level required to maintain the activity of most fish.

Keywords: wild rice straw, fish, winter kill, oxygen depletion, model, natural lakes.

DECOMPOSITION OF WILD RICE (*Zizania aquatica* L.) STRAW AND ITS EFFECT ON THE DEPLETION OF OXYGEN DURING WINTER IN NATURAL LAKES OF NORTHWESTERN ONTARIO

INTRODUCTION

Wild rice (*Zizania aquatica* L.) is an aquatic plant, generally found in shallow areas of lakes and rivers. In northwestern Ontario, germination of wild rice begins in late April or early May. The young plants remain submerged for three to four weeks, after which long ribbon-like leaves emerge and float on the water surface. About mid-June, the stems rise above the water surface and emergent leaves begin to grow. Flowering starts during the early part of July, and in late August the crop is ready for harvesting.

Christianson and Lindner (1981) observed that the lush habitat and thick protective cover provided by wild rice attract fish during much of the summer. When the rice ripens in late August, it becomes a virtual smorgasbord for many of nature's creatures. The ripening grains attract countless birds, animals and aquatic creatures, including several species of fish. Numerous insects, such as *Apamea apamiformis* (wild rice worm), fall into the water and are consumed by sunfish.

Although wild rice has been known to the Ojibway Indians for a long period of time, it only entered an era of commercialization during the last fifteen years. Some of the largest natural stands are located in northwestern Ontario. These stands cover about 8,000 hectares, with total production estimated at 600,000 kilograms of green wild rice in a good year. Northern Ontario, with its thousands of lakes, has a very large potential for growing wild rice. Wild rice producers show ardent interest in planting new lakes because of the increasing popularity of the product. Although, historically, no concern was shown, the question was recently raised concerning the effect of wild rice straw on oxygen depletion in natural lakes.

Depletion of oxygen in natural lakes has been described by several workers: Schindler (1971) and Barica and Mathias (1979). These findings suggest that saturation of oxygen generally varies between 80 and 100 percent at the time of freeze up. During ice cover, some lakes become supersaturated with oxygen, due to photosynthesis, until completely covered with snow. The concentration of dissolved oxygen decreases during snow cover, until the snow melts and light again becomes available for photosynthesis.

Mathias and Barica (1980) reviewed the work of Schindler (1971), Welch (1974), Welch et al (1976) and Barica and Mathias (1979) and concluded that the sediments of eutrophic lakes consumed oxygen about three times faster (0.23 $g/m^2/day$) than those of oligotrophic lakes (0.08 $g/m^2/day$). Water column respiration, however, was about the same (0.01 $g/m^3/day$) for both groups of lakes. They further reported that oxygen consumption was limited by oxygen supply below an average whole lake concentration of 3.8 mg/litre. A similar observation also was made by Hargrave (1972). He noted that the rate of oxygen depletion in the hypolimnion of Lake Estrom was independent of the oxygen concentration from 14-4 mg/litre, but decreased 60% when dissolved oxygen fell below 4 mg/litre.

In order to describe the effect of wild rice straw on the depletion of oxygen during winter, an attempt was made to study the decomposition of wild rice straw in natural lakes of northwestern Ontario.

MATERIALS AND METHODS

DECOMPOSITION OF WILD RICE STRAW

On October 5, 1979, wild rice plants were pulled out of Laurenson Creek (49°46'N 94°29'W), after all seeds had fallen. The roots were separated and the upper vegetative parts were chopped in small pieces (5-10 cm in length) and air dried.

About 20 grams of air dried straw were placed in fine-mesh, nylon bags (25 × 15 cm in size). Five bags of straw were placed together in a fine aluminum screen, as shown in Figure 1. Three lead weights were tied to each set of straw samples to serve as anchors. Five sets of straw samples were placed in each of two waterbodies: Lulu Lake (49°46'N 94°42'W), representing a typical shallow lake, and West Bay (49°46'N 94°34'W), representing a river system.

One set of straw samples (five bags) was taken out at different time intervals over a total period of 350 days. Due to a thick layer of ice, no samples could be taken out of Lulu Lake during March, 1980. The samples were washed gently with tap water and dried in an oven at 70°C for at least 72 hours. The loss in weight, after different time intervals of placement in the lakes, was calculated and used as the criterion for decomposition of the wild rice straw.

TOTAL PRODUCTION OF WILD RICE STRAW

Sandy Lake (49°47'N 94°40'W) showed a bumper wild rice crop during the year 1980. Wild rice plants from three plots of 1 m^2 in size were pulled out on October 9, 1980, and taken to the laboratory in large plastic bags. The roots were separated from the top vegetative parts, and both portions of the plants were dried separately in an oven at 70°C. The average dry weight of the roots and the top vegetative parts was determined and used as the amount of wild rice straw which can be expected to be added from a good wild rice crop.

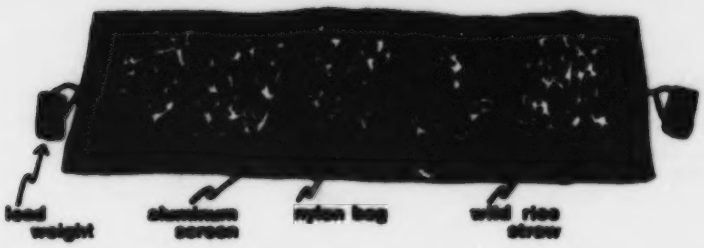

Figure 1. A set of wild rice straw samples used in the decomposition study.

RESULTS AND DISCUSSION

Depletion of oxygen is considered to be one of the major factors causing winter kill of fish. A major portion of dissolved oxygen generally is used by micro-organisms during the decomposition of detritus.

Growth of wild rice in a lake would increase the total amount of detritus and thereby increase the overall oxygen consumption. The total amount of wild rice straw produced from a high density wild rice crop (Sandy Lake data) was estimated to be 3,964 kilograms per hectare. It included 3,200 kilograms of top vegetative parts and 764 kilograms of roots. The straw added from a low to medium density crop would be much lower than these amounts. The rates of decompcsition of wild rice straw in Lulu Lake and West Bay are given in Figure 2.

Initial loss in weight, from October 17 to November 7, 1979 (Figure 2), appears to be partly of a chemical nature, when water soluble components of the straw are lost. The rest of the decomposition was considered to be biological, carried out mostly by micro-organisms. The decomposition of wild rice straw from November 7, 1979, to June 17, 1980, was 0.16 percent per day. The period from December 1 to March 15 (3½ months) can be taken as the time of snow cover in northwestern Ontario, when oxygen levels generally decrease in lakes due to restricted or no photosynthesis. The total consumption of oxygen for the decomposition of wild rice straw was calculated as follows:

CONSUMPTION OF OXYGEN BY WILD RICE STRAW

Based on carbon analysis and weight loss of wild rice straw, the total loss of carbon during the period from December 1, 1979, to March 15, 1980, in Lulu Lake was 282.9 kg.

Reaction: $C + O_2 \rightarrow CO_2 \uparrow$

$12g \quad 32g \quad 44g$

Total consumption of oxygen for the decomposition of straw during winter equals:

$$282.9 \times \frac{32}{12} = 754.4 \text{ kg } O_2/\text{hectare}/105 \text{ days}$$

or $= 7.18 \text{ kg } O_2/\text{hectare/day}$

or $= 0.718 \text{ g } O_2/m^2/\text{day}$.

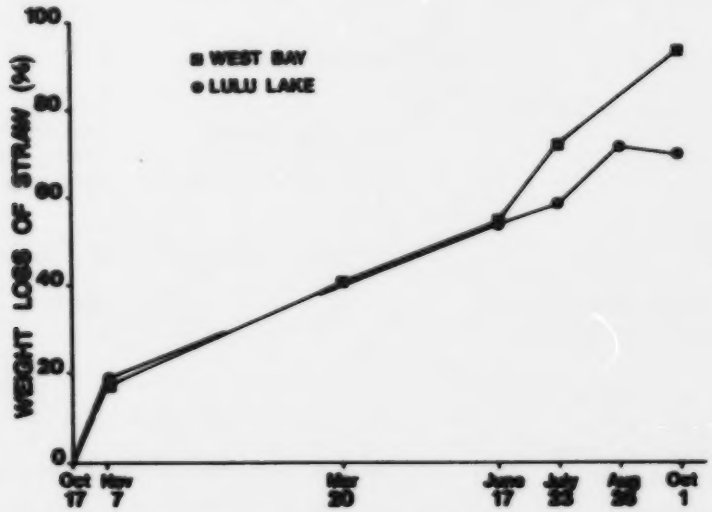

Figure 2. Decomposition of wild rice straw in two different waterbodies of northwestern Ontario.

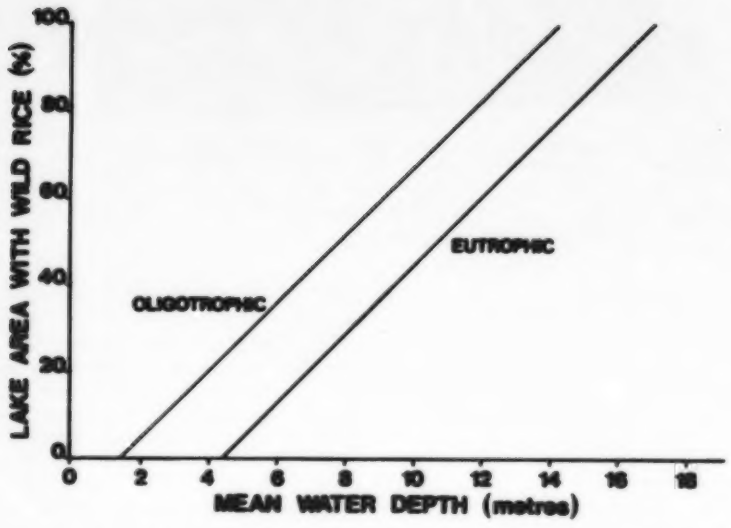

Figure 3. Relationship between mean water depth and percent surface area of a lake, where the production of wild rice does not limit the activity of most fish.

TOTAL AVAILABLE OXYGEN

Considering the initial concentration of oxygen at 80 percent saturation at 2°C, and using a correction factor of 0.96 for the altitude of lakes in northwestern Ontario (Trusdale et al 1955), the oxygen concentration at freeze up would be 10.67 mg/litre.

The critical level of oxygen at low temperatures, above which most fish could maintain their activity (Wheaton 1977, Jones 1964), is 4mg/litre. Therefore, available oxygen above the critical level is 10.67 - 4.00 or 6.67 mg/litre. And, the total amount of oxygen above the critical level in a lake is:

$$66.7 \times A \times \bar{Z} \text{ kilograms,}$$

where A = surface area of the lake in hectares,

and $\bar{Z}$ = mean water depth in metres.

OXYGEN BALANCE IN RELATION TO FISH AND WILD RICE PRODUCTION

No winter kill of fish would occur as long as the following equation applies in a lake:

$$\begin{matrix}\text{Total available oxygen above the critical level for fish}\end{matrix} - \begin{matrix}\text{Total consumption of oxygen during the period of snow cover in a lake}\end{matrix} \geq 0 \qquad \text{Eq.(1)}$$

Using Equation (1), the following equations were developed for different types of lakes:

Eutrophic Lakes:

Available oxygen above the critical level for fish (kg) = Consumption of oxygen during the period of snow cover in a lake (kg)

$$66.7\ A\ \bar{Z} = 754.4\ A\frac{A_w}{A} + 241.5\ A + 10.5\ A\bar{Z}$$

straw | sediment benthos fish | water column

or $$56.2\ \bar{Z} = 754.4\ \frac{A_w}{A} + 241.5 \qquad \text{Eq.(2)}$$

Oligotrophic Lakes:

Available oxygen above the critical level for fish (kg) = Consumption of oxygen during the period of snow cover in a lake (kg)

$$66.7\ A\ \bar{Z} = 754.4\ A\frac{A_w}{A} + 84\ A + 10.5\ A\ \bar{Z}$$

straw | sediment benthos fish | water column

or $$56.2\ \bar{Z} = 754.4\ \frac{A_w}{A} + 84 \qquad \text{Eq.(3)}$$

where A = Surface area of the lake in hectares,

$\bar{Z}$ = Mean water depth in metres, and

A_w = Area of the wild rice crop in hectares.

Using Equations (2) and (3), relationships were developed between mean water depth and percent surface area of oligotrophic and eutrophic lakes, where the growth of wild rice will not limit the concentration of oxygen required to maintain the activity of most fish (Fig. 3).

Figure 3 shows that a winter kill of fish would occur, even without any wild rice growth, in oligotrophic and eutrophic lakes with mean water depths of 1.5 and 4.3 metres or less, respectively. These relatively shallow lakes are generally ideal for wild rice. Therefore, it would be much more economical to use them for that purpose.

In oligotrophic lakes with mean water depths between 1.5 and 14.9 metres, and in eutrophic lakes with mean water depths between 4.3 and 17.7 metres, a certain percentage of the total surface area of the lake, as given by Figure 3, can be used for growing wild rice, without limiting the concentration of oxygen required to maintain the activity of most fish

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